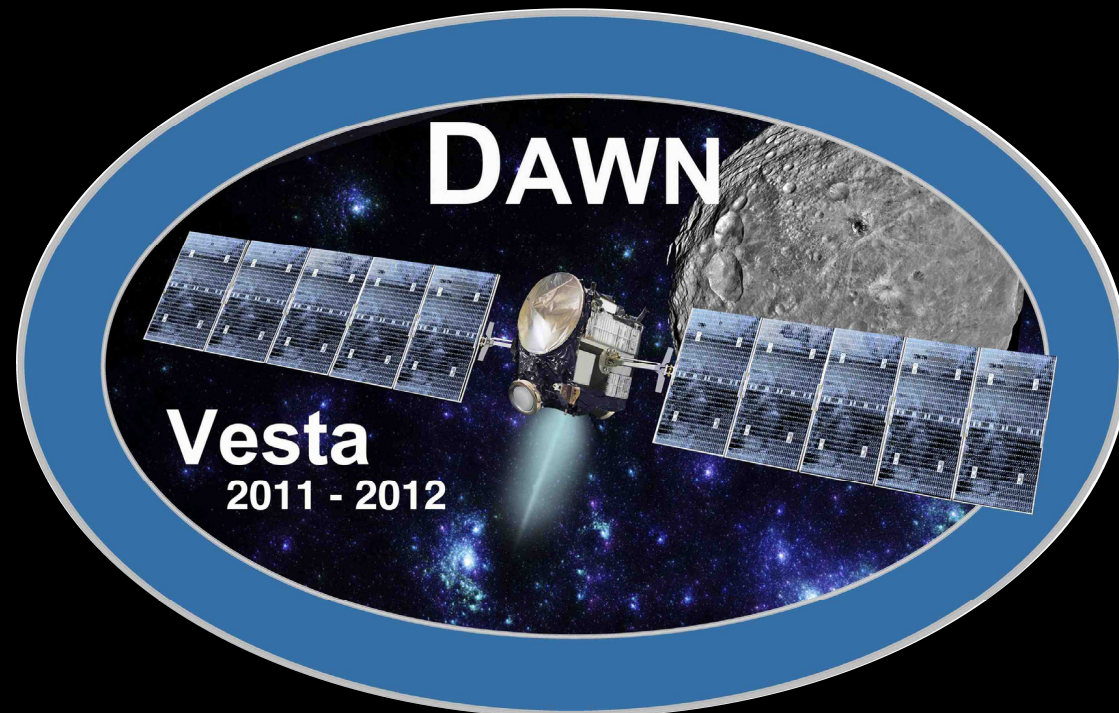


Automation and Process Improvement Enables a Small Team To Operate a Low Thrust Mission In Orbit Around the Asteroid Vesta



Timothy M. Weise
June 13, 2012



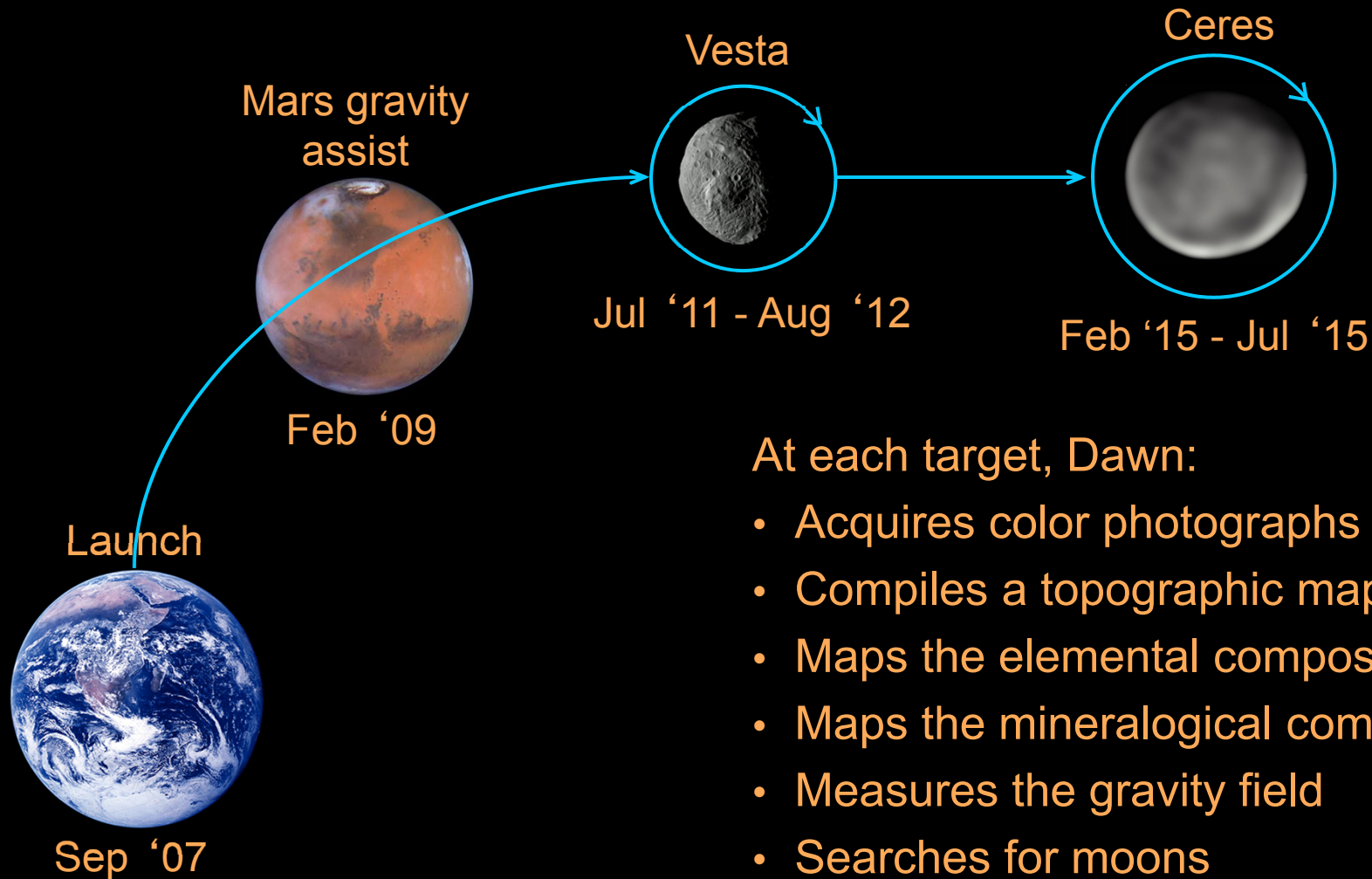
Agenda

- Mission Overview
- Uplink Process Evolution
- Downlink Process Evolution
- Conclusions

Dawn Mission Overview

- NASA's 9th Discovery Class Mission
- Will study the two largest asteroids in the asteroid belt – Vesta and Ceres
- Managed and operated by JPL
- Spacecraft supplied by Orbital Sciences Corporation
- Instruments supplied by:
 - GRaND – Los Alamos National Laboratory, NM, USA
 - Framing Camera - Max-Planck-Institut für Sonnensystemforschung, Katlenburg-Lindau, Germany
 - Visible and Infrared Mapping Spectrometer - Galileo Avionica, Florence, Italy

Mission Itinerary



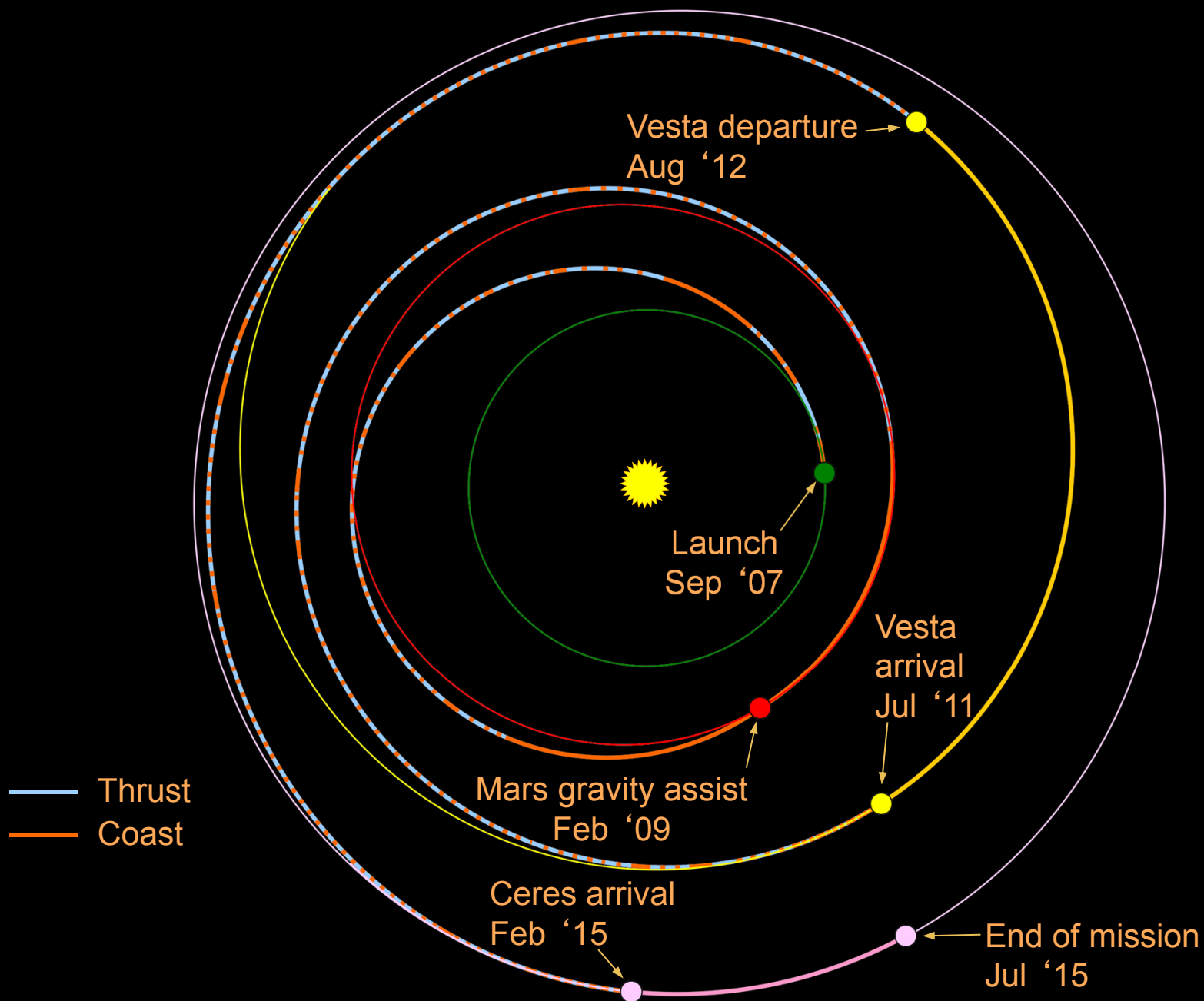
At each target, Dawn:

- Acquires color photographs
- Compiles a topographic map
- Maps the elemental composition
- Maps the mineralogical composition
- Measures the gravity field
- Searches for moons

Note: Text not to scale.

Solar Electric Propulsion (SEP)

- Dawn uses SEP to achieve necessary delta-V to accomplish mission
- Requires many hours of thruster on-time (23,000 hours since launch)
- Thrusting and communication with Earth are exclusive

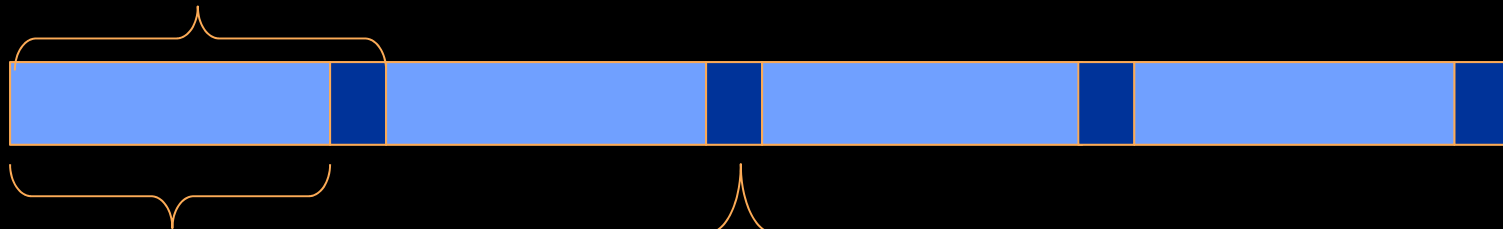


Early Cruise Overview

- Three to four weeks to develop four to five weeks of spacecraft activities
- Typically one 8-hour communication pass per week, ion thrusting for remainder of week

Example Thrust Sequence

In cruise: one week; at Vesta: variable duration



Ion Thrusting:

- Turn to thrust point
- Turn on Ion Thruster
- Turn off Ion Thruster

Communications Pass:

- Turn to Earth Point
- Configure Communications
- Playback data
- Disable Communications

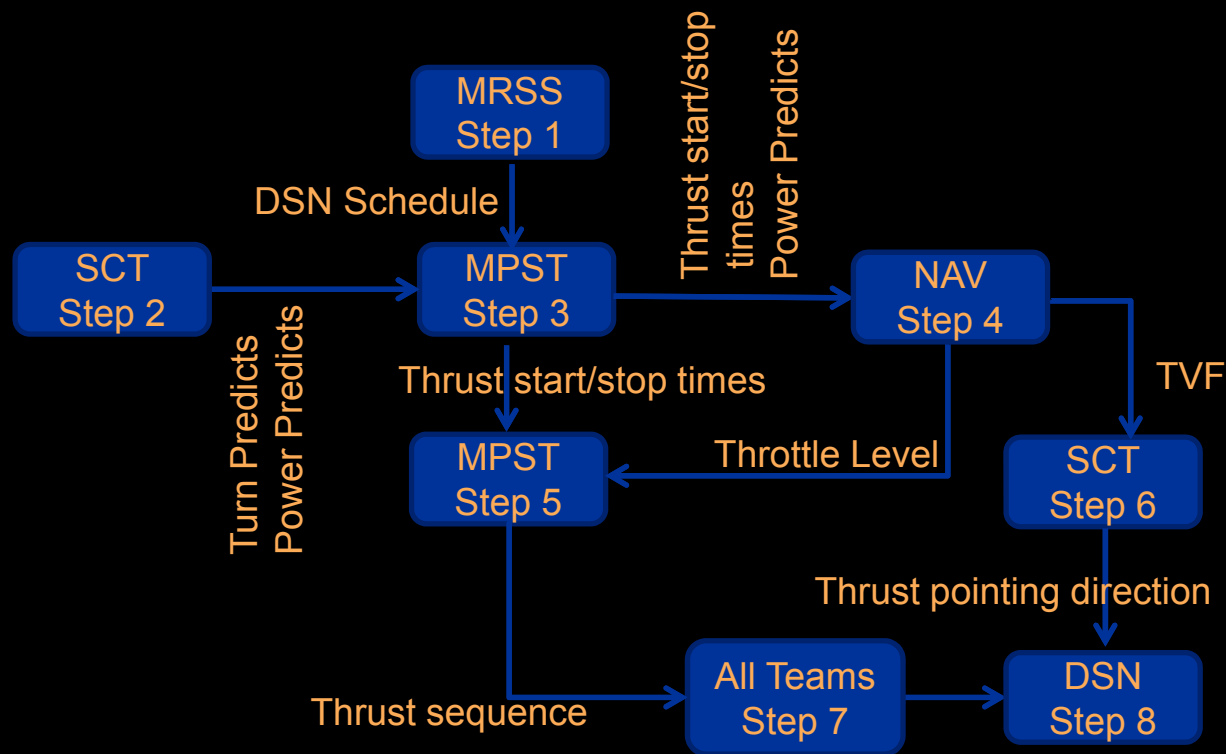
Changes at Vesta

- Increased tracking/irregular schedule
 - Orbit transfers
 - Maneuver execution error and orbit determination
 - Gravity field determination after arrival
 - Science Orbits
 - Collect science data on lit half of orbit, transmit to Earth on dark side in Survey and HAMO (High Altitude Mapping Orbit)

Uplink Process Overview

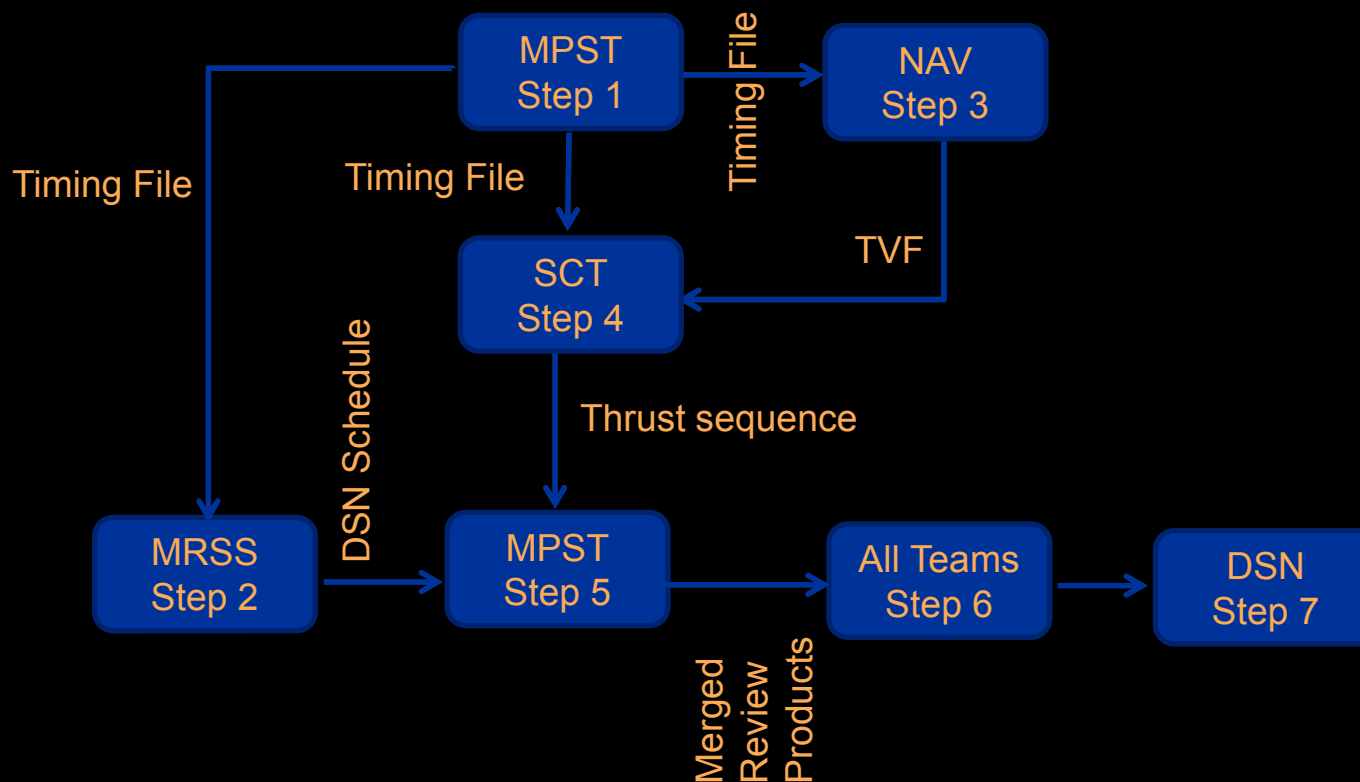
- Uplink process includes the development, build, test, review of command files to send to the spacecraft
- Cruise:
 - Sequences to fire ion thruster
 - Engineering activities
- At Vesta:
 - Sequences to acquire science data
 - Orbit transfers and orbit maintenance
 - Required accelerated development timeline (3 days for a thrust sequence)

Thrust Sequence Uplink Process – early Cruise



- The same information is represented differently in different steps, requiring team review to ensure consistency

Thrust Sequence Uplink Process – at Vesta



- The timing file controlled all of the timing and each step is based one control file, thus ensuring consistency up front

Uplink Process - Epochs

- Commands can be defined relative to:
 - Absolute time (2012-165 at 12:30)
 - Epoch (15th descending equator crossing)
 - Orbit geometry defined in a separate file
- Cruise process used absolute times
- Vesta process used epochs
 - Reprocess command files using a new orbit geometry file

Uplink Process - Epochs

- Using epochs:
 - Reduced rebuild and review time from 7 days to 3 days
 - Reduced orbit propagation duration, and thus improved accuracy
 - Reduced risk of introducing errors since updates were computer generated

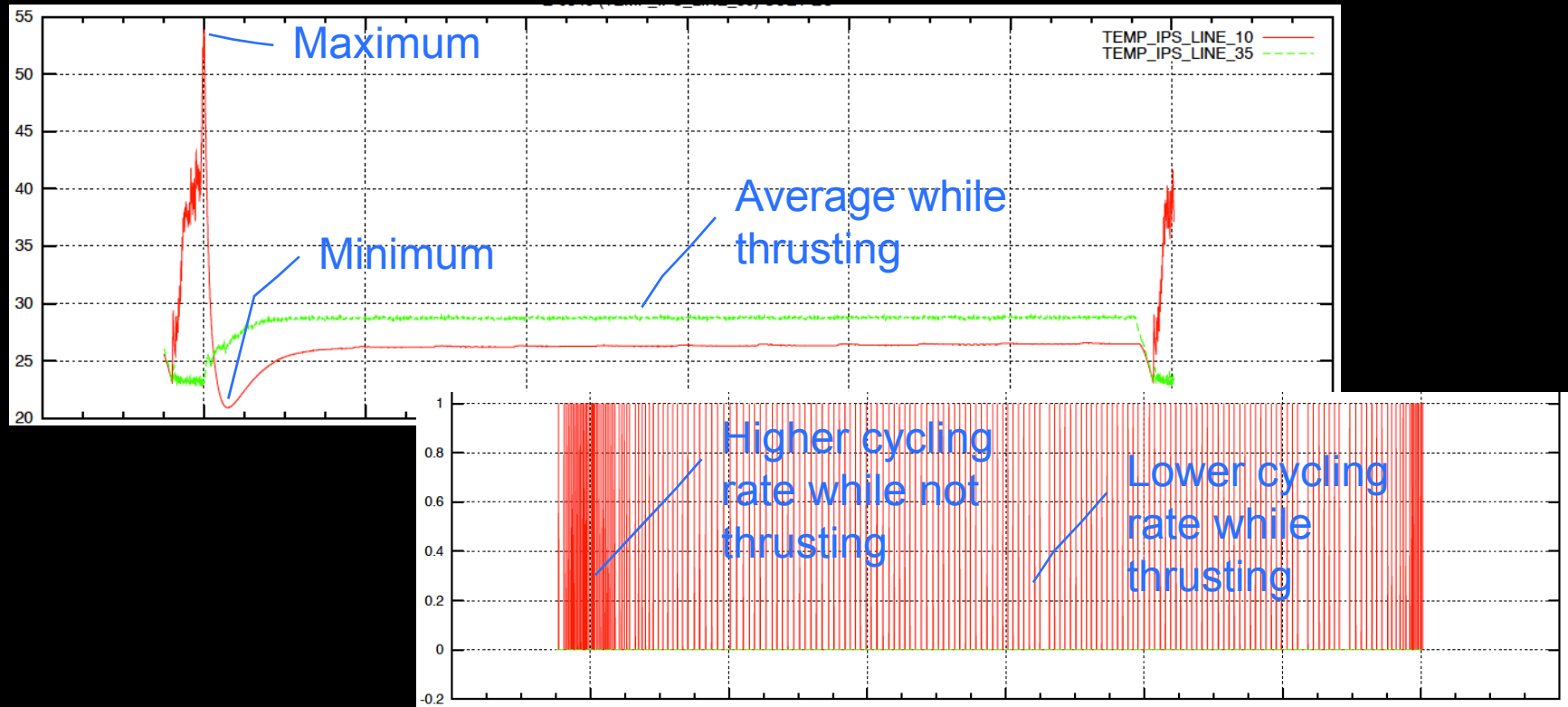
Downlink Process Overview

- Real time health/safety monitoring
- Data playback review
- Performance/trend assessment

Downlink Process Automation

- Automatic Alarm Notification
 - Rapid, automatic text message/pages to alert system engineers immediately of issues with the flight system
- Batch telemetry queries
 - Schedule one tool to supply all subsystem and system engineers with plots of data in email

Trending Tool



- Needed a way to keep track of new maximums, minimums, and averages
- Tool execution added to the batch queries

Rule Tool

- Automatically process data file to check if a telemetry channel is:
 - Greater than, less than, equal to, changed, or changed by a particular amount
- Outputs a summary report and detail report
- Allows engineer to review summary report quickly, then analyze any issues in detail

Improvements at Vesta

- Auto scheduler
 - More tools to schedule
 - Increased frequency, but irregular schedule
- Status report
 - Emails team of current spacecraft status and selected rules reports for a quick look assessment
 - If any issues are identified, then the engineers can look into the details

Improvements at Vesta

- IPS report
 - Navigation team required an IPS thrust reconstruction to improve maneuver accuracy
 - This was not required in cruise
 - Previous process was manual
 - A new script automatically computed the thrust reconstruction and delivered the report

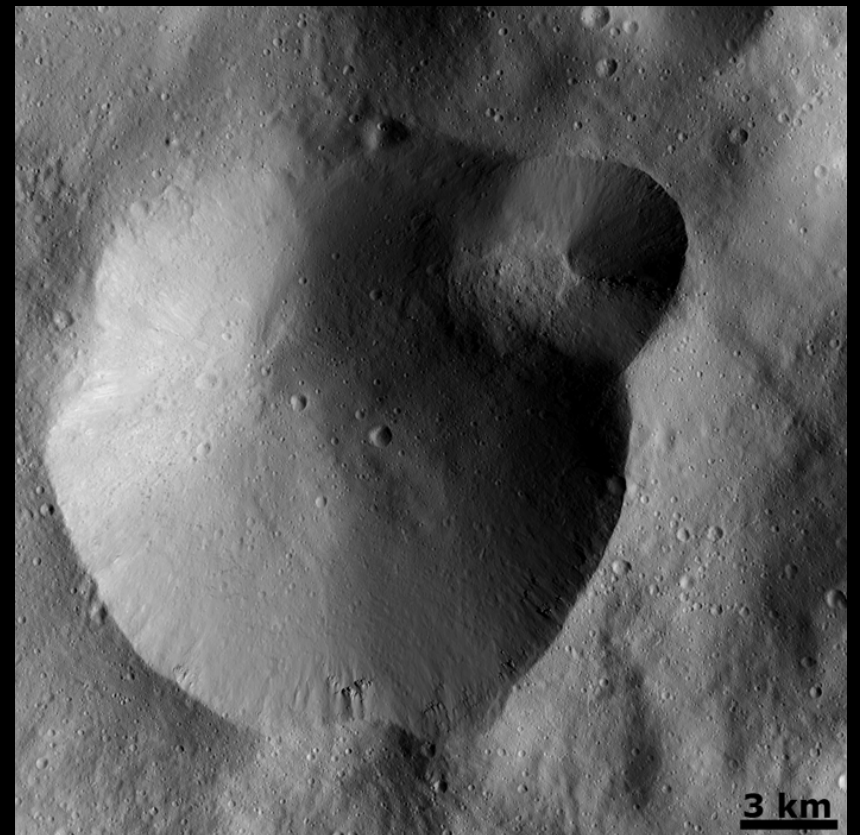
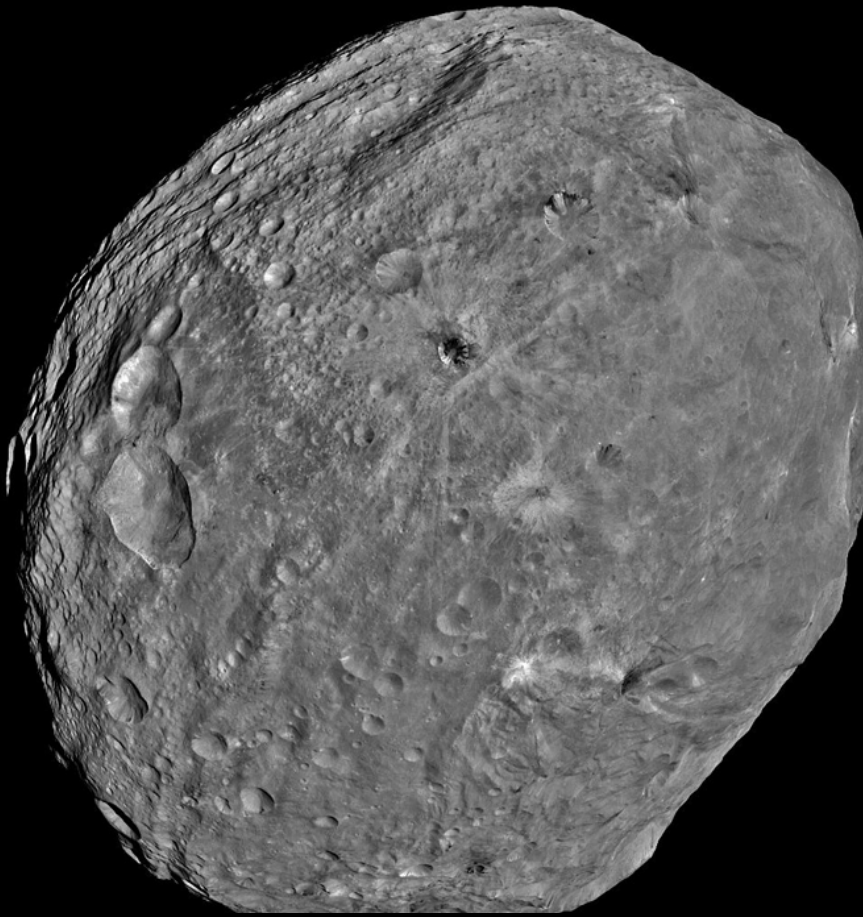
On Approach – June 20, 2011



Dawn



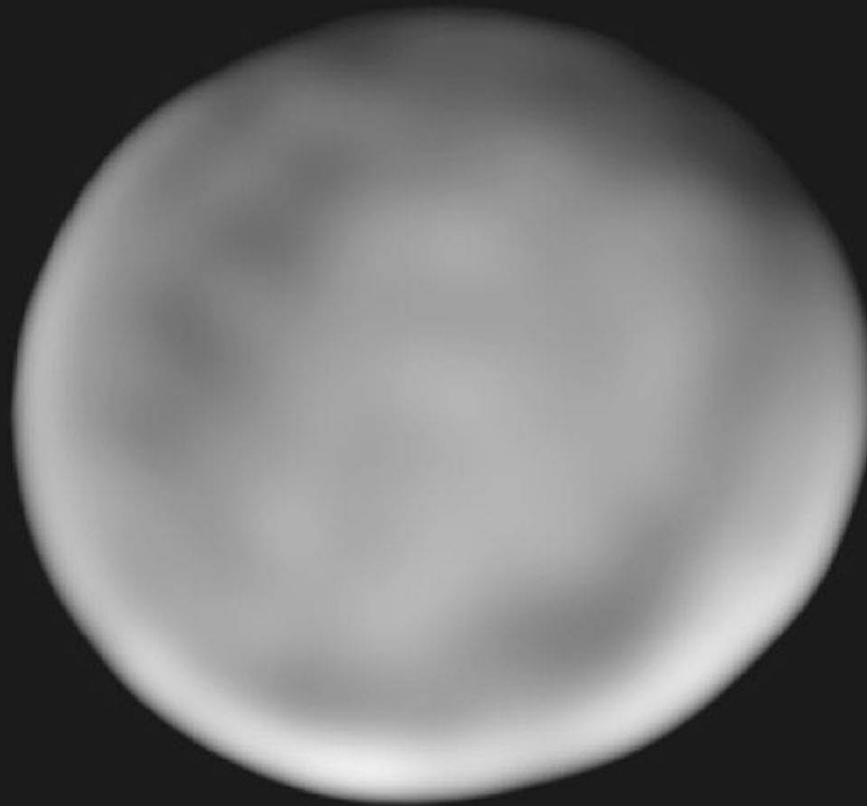
Hubble
Space
Telescope



Conclusions

- These improvements enabled the small operations team to maintain rigor even with the increased workload of science operations, ultimately achieving the tremendous science returns
- Many of the improvements will apply during cruise to Ceres, and again at Ceres

The next challenge - Ceres



Questions?

Credit: Dumas C. et al., NASA-JPL